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October 26, 1989

Mr. Stephen W. Holt
Senior Environmental Engineer
NL Industries, Inc.
P.O. Box 1090
Wyckoffs Mill Road
Highstown, NJ 08520

Dear Mr. Holt:

Pursuant to our discussion on October 20, 1989 I have enclosed the articles titled:

"Lead in Soil: Recommended Maximum Permissible Levels"

"Reducing Lead Uptake in Lettuce"

"A Study of Soil Contamination and Plant Lead Uptake in Boston Urban Gardens"

Should you require additional information, please contact me.

Sincerely,

Kenneth M. Miller

Kenneth M. Miller, Project Manager
Federal Site Management Unit
Remedial Project Management Section
Division of Land Pollution Control

KMM:pss

cc: DLPC File
Brad Bradley

ENVIRONMENTAL RESEARCH 49, 136–142 (1989)

Lead in Soil: Recommended Maximum Permissible Levels[1]

SHANTHA MADHAVAN,*[,2] KENNETH D. ROSENMAN,†[,2] AND TERRY SHEHATA‡

*Albert Einstein College of Medicine, Bronx, New York 10461; †Michigan State University, B338 Clinical Center, E. Lansing, Michigan 48824-1317; and ‡Division of Occupational and Environmental Health, New Jersey Department of Health, Trenton, New Jersey 08625

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INTRODUCTION

Environmental exposure to lead has long been recognized as a public health problem particularly among children. The vulnerability of the age group 1 to 5 years to soil lead is enhanced because of their hand to mouth activities, pica, and a high rate of intestinal absorption. Excessive concentration of lead in soil has been shown to increase lead levels in children (Lin-Fu, 1973a, b; Mielke *et al.*, 1983; Duggan and Williams, 1977; Brunekreef *et al.*, 1981; Roels *et al.*, 1980; Schmitt *et al.*, 1979). As a result, there has been an increasing awareness for the need to monitor lead levels in soil and to control soil lead contamination by maintaining a "safe" level. Given the widespread presence of lead in urban soil, reduction of lead to background uncontaminated levels is not possible (National Academy of Sciences, 1980). The major focus of this report is to propose a "safe" or permissible level of lead in soil in highly urbanized areas, below which potential adverse health effects will be minimized.

BACKGROUND

Environmental Assessment

Soil lead contamination has been attributed to various sources (American Academy of Pediatrics, 1985). Flaking lead paint, particularly in and around houses or buildings has been considered as a major source of contamination. Air-borne lead particles deposited in soil is another important source. Emissions from industries, from incinerators and similar sources, and from vehicular traffic using leaded gasoline contribute to soil lead content. Urban environments receive a higher deposition of lead from vehicular emissions than rural areas. Furthermore, lead concentration in urban soils are not evenly distributed (Mielke *et al.*, 1983).

In general, lead tends to remain at the surface soil and concentrations are lower at deeper layers. Lead-contaminated soil and dust have been identified as important sources of exposure for children especially in an urban setting (Duggan and Williams, 1977). Wide variations in soil lead levels have been observed. Studies

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[2] Formerly Division of Occupational and Environmental Health, New Jersey Department of Health, Trenton, NJ 08625.

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have reported values ranging from less than 100 ppm to well over 11,000 ppm (National Academy of Sciences, 1980). In a recent study in Baltimore, the lead levels in garden soil samples ranged from 1.0 ppm to over 10,000 ppm with a median of 100 ppm (Mielke *et al.*, 1983). Spittler and his co-workers did a similar study on garden soil in Boston (Spittler and Feder, 1979). Soil lead levels were higher in inner-cities and near roadways. Also, front yards of homes facing roadways had higher lead contamination than backyards. Automobile and industrial emissions have been found to be mainly responsible for increase in urban soil lead levels.

Health Effects

Severe lead toxicity often causes encephalopathy. Prevention of this serious sequelae of lead poisoning was a major focus in the 1960s (Mahaffey, 1983). During the 1970s, recognition of chronic exposure of lead and its cumulative effect shifted the emphasis to the understanding of the adverse effects of low levels of lead intoxication. The study by Needleman *et al.* (1979) showed a positive relationship of lead in shed milk teeth with poor ratings from classroom behavior. These findings supported the "no threshold" view and also indicated the need for more attention to be given to cumulative adverse effects of lead at low levels of intake. A recent study in Boston (Bellinger *et al.*, 1987) emphasized this view with its findings on fetal lead exposure associated with retardation of mental development.

The blood lead concentration has been generally accepted as the best measure of the external dose of lead (National Academy of Sciences, 1980), although it is not considered as a reliable index of past absorption or of toxicity per se. However, Needleman *et al.* (1979) had observed that children with higher tooth lead levels tended to have had higher blood lead levels previously (4 or 5 years prior to tooth shedding).

In recent years, progress has been made in achieving the goal to remove lead from the environment of children before it enters their bodies. The Second National Health and Nutrition Examination Survey (NHANES-II) has established average blood lead levels for the U.S. population (Mahaffey *et al.*, 1982). These data demonstrated that urbanization was associated with an increased blood level. Lead levels in blacks were on an average 6 μg/dl higher than those in whites. The lowest blood lead associated with adverse biological effects has been observed to be 10 μg/dl (Minnesota Department of Health, 1984). ALAD (Δ-aminolevulinic acid dehydratase) inhibition is associated with this low level. More serious conditions such as anemia and neurologic effects occur at higher levels of blood lead elevation.

Leaded gasoline makes a substantial contribution to soil and dust lead levels (Caprio *et al.*, 1974). The reduction of lead in gasoline and removal of lead in paint for residential areas have been primarily responsible for a decline in the average blood lead levels in children on a national basis. In areas with very high concentrations of lead in soil and dust, large-scale cleanup operations of soil or relocation of the population will be the ideal remedial actions to protect children from undue lead exposure. Such responsibilities for regulating lead exposure include the setting up of acceptable levels of lead in soil by government agencies.

MATERIALS AND METHODS

Several studies have found that lead in soil is positively correlated with blood lead in children (Brunekreef, 1981; Roels *et al.*, 1980; Schmitt *et al.*, 1979). The U.S. Environmental Protection Agency (EPA) estimated the blood lead soil slope as ranging from 0.6 to 6.8 μg/dl per 1000 μg/g of soil lead concentration (U.S. Environmental Protection Agency, 1983). Available data on the estimates of the amount of soil ingested by children showed 100-fold variation and were not considered useful in deriving a "safe" soil level (Binder *et al.*, 1986; Clausing *et al.*, 1987; Hawley, 1985).

Duggan (1980) did an assessment of the relationship of blood lead and lead in soil/dust, based on 21 samples out of nine studies, which had data permitting a quantitative estimation of the blood lead slope. His estimate was an increment of 5 μg/dl of blood lead per 1000 ppm of lead in soil. These studies varied a great deal in the type of soil and the study population. Soil or dust source included various types such as boot tray dust, house dust, outdoor dust, playground dust, and soil. Most of these studies were on children under 5 years of age, a few on older children up to 14 years, and one on a mixed population of adults and children. The blood lead slopes, computed by Duggan for all 21 samples, were available, ranging from 0.6 μg/dl to 65 μg/dl per 1000 ppm of lead in soil.

We based our analysis on 8 of Duggan's 21 slope estimates. We selected these 8 slopes because soil was the only source of lead, not house dust, etc., and only blood levels from children under 12 years, the most susceptible group to lead toxicity, were used to derive the slopes.

RESULTS AND DISCUSSION

The results of limited soil sampling in New Jersey found that median values of lead in surface soil samples from different areas in New Jersey varied from 4 ppm to 1245 ppm (New Jersey State Department of Health, 1985). The overall median levels were 238 and 73 ppm for suspected contaminated and control sites, respectively. Newark had the highest median of 1245 ppm followed by Jersey City (668 ppm), Secaucus (495 ppm), and other towns with levels below 400 ppm. Samples from areas in Princeton and Flemington were below 100 ppm. As observed in earlier studies, front yards of homes in Newark had a higher level (1755 ppm) than backyards (1060 ppm).

Table 1 shows the slopes ranging from 0.6 to 65 μg/dl per 1000 ppm of the eight studies selected to derive an acceptable level for lead in soil. As lead levels in blood are known to be distributed lognormally, and the range for slopes (0.6–65.0 μg/dl) is very wide, analysis was done on base 10 log transformations of the slopes. The mean of the base 10-logs is 0.5321 with a standard error of 0.2435. Transforming back, the geometric mean and the geometric standard error of the slopes is 3.41 ± 1.75 μg/dl. Applying the "worst-case" or upper-limit analysis to the base 10 logs, the one-tailed 95% upper confidence limit equals 0.5321 + 1.65 × 0.2435 = 0.9339 (American Industrial Health Council, 1985; Wilson and

TABLE 1
DATA RELATING TO LEAD IN BLOOD WITH LEAD IN SOIL[a]

Author and reference	Number of persons in study	Age of persons (years)	Slope (μg/dl/1000 ppm)
Angle *et al.* (i)	153	2–5	65.0
Angle *et al.* (ii)	25	10–12	15.0
Barltrop *et al.*	82	2	0.6
Galke *et al.* (i)	187	up to 5	3.3
Galke *et al.* (ii)	187	up to 5	1.6
Shellshear *et al.*	68	1–5	3.9
Yankel *et al.* (i)	1149	1–9	0.6
Yankel *et al.* (ii)	1149	2–3	2.5

[a] *Source:* Duggan (1980).

Crouch, 1982). Transforming back, the antilog is 0.9339–8.5877 μg/dl per 1000 ppm of lead in soil. This slope corresponds to the worst case situation.

Using the slope 8.59 μg/dl, soil concentrations have been calculated for different amounts of blood lead contributed from soil, as shown in Table 2. Having computed the soil concentration for different amounts of blood lead contributed through soil, the next important consideration is the choice of the permissible amount of blood lead from soil. The soil lead concentration corresponding to this blood lead level would be the suggested lead permissible level. Keeping in mind the background level of blood lead for children under 12 years, the ideal situation would be to have no increment in blood lead level contributed from soil. This stringent condition demands a zero level concentration of lead in soil. Looking at estimates of soil lead levels available from various studies in the United States and elsewhere, one realizes that to bring down the lead concentration to zero would be an impractical task. As shown in Table 2, even for 1 μg/dl of blood lead from soil, the soil concentration has to be around 100 ppm. If 5 μg/dl of blood lead is chosen as a tolerable level, the corresponding soil concentration is 582 ppm, rounded off to a figure of 600 ppm. With a suggested permissible level of 600 ppm, it can be stated with reasonable certainty that this soil concentration will contribute no more than 5 μg/dl to blood lead for children under 12 years. The selection of 5

TABLE 2
LEAD CONCENTRATION IN SOIL BY BLOOD LEAD CONTRIBUTION FROM SOIL

Blood lead from soil[a] (μg/dl)	Soil concentration (ppm) at 95% upper confidence limit of 8.59 μg/dl 1000 ppm
1	116
5	582
10	1164
15	1746
20	2328
25	2910

[a] In addition to background level.

μg/dl is somewhat arbitrary. The median blood lead of children 6 months to 5 years between 1976 and 1980 was reported to be 16 μg/dl for whites and 20 μg/dl for blacks. Since lead accumulates there is no absolutely "tolerable" increase of blood level. Allowing an increase of 5 μg/dl above the median level is probably not advisable. The national median levels, however, are probably partially attributable to soil contamination. Table 2 therefore needs to be used as a guideline to the upper limit of accumulation not as a standard which if met guarantees absolute safety.

This suggested level of 600 ppm lies within the range given by the Center for Disease Control (1985) in the following statement:

> "In general, lead in soil and dust appears to be responsible for blood lead levels in children increasing above background level when the concentration in the soil or dust exceeds 500–1000 ppm."

A similar analysis was done by the EPA. (U.S. EPA, 1983). In that analysis the value of 65 μg/dl/1000 ppm from one study (Angle, see Table 1) was not included. Eliminating this outlier would change the 95% upper confidence limit of the slope from 8.59 that we used, to 4.52 μg/dl/1000 ppm. This would approximately double the soil levels presented in Table 2. Eliminating the upper and lower outliers in Table 1 would not appreciably change the slope or values in Table 2. Because of the uncertainty involved in selecting a "safe" level we do not feel that it is warranted to exclude the data at either extreme.

Furthermore, it is important to keep in mind that exposure of children to lead-contaminated soil or dust is enhanced when they play on nongrassy surfaces than on grass-covered areas (Lewis and Clark County Health Department *et al.*, 1986), a scenario similar to the vulnerability of children exhibiting mouthing behavior.

In conclusion, maximum permissible levels of lead in soil have been recommended by the New Jersey State Department of Health, based on the dose–response relationship of lead in soil and blood lead in children as follows:

1. A maximum permissible level of 250 ppm of lead in soil is recommended in areas without grass cover and repeatedly used by children below 5 years of age among whom mouthing objects is highly prevalent. This level may add at the most about 2 μg/dl to the blood lead level of children.
2. A maximum permissible level of 600 ppm of lead in soil is recommended in areas repeatedly used by children below 12 years of age. This level may add at the most 5 μg/dl to blood lead level of children.
3. A maximum permissible level of 1000 ppm of lead in soil is recommended in areas such as industrial parks or along streets and highways or in other areas infrequented by children. Although these areas are not expected to be places where children play, we do not feel that this can always be assured. Additionally, we are concerned about migration of lead off these sites on the footwear or clothes of adults.

The Department of Health also recommends that municipalities should consider the passage of local ordinances prohibiting the development of residential areas in lead-contaminated soil unless the lead soil concentration is reduced to the appropriate maximum permissible level.

SUMMARY

Lead in soil has been recognized as a public health problem, particularly among children. In recent years, attention has been directed to cumulative adverse effects of lead at low levels of intake. Lead-contaminated soil and dust have been identified as important contributors to blood lead levels. Based on available data on blood lead and lead in soil, an approach has been developed to suggest a permissible level of lead in soil, below which there will be reasonable certainty that adverse health effects will not occur. An acceptable level of 600 ppm of lead in soil suggested as a "safe" level would contribute no more than 5 μg/dl to total blood lead of children under 12 years of age. Maximum permissible levels of lead in soil have been recommended based on the dose–response relationship of lead in soil and blood lead in children.

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Reducing Lead Uptake in Lettuce

N.L. Bassuk[1]

Urban Horticulture Institute, Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, NY 14853

Additional index words. heavy metals, engine emissions, airborne lead deposition, *Lactuca sativa*, phosphorus, organic matter

Abstract. **Lettuce plants (*Lactuca sativa* L. 'Black Seeded Simpson') were grown under greenhouse conditions in soils artificially contaminated with $PbCl_2$. The addition of organic matter or P substantially reduced Pb uptake. Different types of organic matter reduced uptake in the following way, from most to least effective, respectively: muck soil > manure > ground-up leaves > sphagnum peat. The addition of 100 ppm or greater P also reduced Pb uptake. Lead deposited onto leaves from the emissions of a gasoline engine could be removed by washing leaves in 1% aqueous acetic acid or 0.5% liquid detergent solution.**

During the past 10 years, there have been increasing numbers of people growing their own vegetables in inner-city areas. This trend has given rise to some concern about the heavy metal content of city-grown produce, particularly its Pb content (1, 6). The World Health Organization recommends that adult daily intake of Pb not exceed 254 $\mu g \cdot day^{-1}$ (14). Children under 3 years of age who are most susceptible to Pb toxicity should take in no more than 100–200 $\mu g \cdot day^{-1}$, according to Mahaffey (8).

Soils ranging in Pb content from 200–6000 ppm have been documented in many cities including New York, Boston, Baltimore, London, Caracas and Christchurch, New Zealand (2, 3, 6, 11). Although Pb is not particularly mobile in the soil, under some conditions it can be taken up in substantial quantities by plants growing in contaminated soil (1). Lead also is deposited directly onto growing leaves from automobile emissions, making it difficult to separate deposited from translocated lead (13).

Numerous studies have documented that Pb levels rise in the soil with nearness to traffic (12, 13). The other major source of Pb in urban garden soils comes from building rubble, where Pb-based paint was used (1).

Several factors affect Pb content in urban-grown vegetables, including soil pH, level of Pb in the soil, organic matter content, cation exchange capacity, presence of other elements (especially P and S), plant age and species, part of the plant eaten (leaf, root, or fruit) and nearness to automobile emissions (1, 6).

The objectives of this project were to develop practical recommendations for the urban gardener to prevent Pb uptake by plant roots and to find a method for removing airborne Pb particulates from plant leaves.

$PbCl_2$ was added to a clay loam soil (pH 6.8), which had a background level of 28 ppm Pb, resulting in soil Pb concentrations of 635 and 3520 ppm. Phosphorus in the form of $Ca(H_2PO_4)_2$ was mixed in the Pb contaminated soils to achieve P readings of 50, 100, 215 and 400 ppm after moist incubation for one month. This form of P was used based on its previously reported effectiveness in reducing Pb uptake from contaminated soils (15). In another experiment, varying proportions of organic matter [100%, 75%, 50%, or 25% (v/v)] were incorporated into the 3520 ppm Pb soil. Four types of organic matter were used: muck soil; well-decomposed manure; dried, ground-up leaves; and sphagnum peat. $PbCl_2$ was added to adjust for the dilution effect of the added organic matter, and these treatments also were incubated moist for one month.

Two-week-old seedlings of 'Black Seeded Simpson' were transplanted into 2.36-cm (6-inch) pots containing the treated soils. Depending on the experiment, pots were replicated 3, 5, or 6 times, completely randomized, and grown in a [21°/16°C (day/night)] greenhouse for 3 months, after which time the tops were harvested, dried, and ground in a Wiley mill.

Potted seedlings were also exposed to the exhaust fumes from a 2-stroke gasoline engine that used leaded gasoline. Twenty 2-week old seedlings were potted into clean soil with all exposed soil covered by aluminum foil and then placed in a ventilated clear-sided box while cooled exhaust was blown over their foliage for 5 min twice a day at 10:00 AM and 3:00 PM for 3 months. The tops then were harvested and treated in the following ways: washed with tap water, 1% aqueous acetic acid (vinegar), 0.5% liquid detergent solution, or not washed. One gallon (3.78 liters) of washing solution was made up for each replicate, which was individually agitated in it for 2 min. An ungassed greenhouse-grown control treatment also was included. Following the washing treatments, the tops were dried and ground.

Five-gram samples of all replicates of all experimental treatments were ashed at 450°C and the residues taken up in HCl. Lead was analyzed by atomic absorption spectroscopy. Soil Pb was analyzed by digesting each sample overnight in 8 N nitric acid, filtered, diluted, and analyzed using atomic absorption spectroscopy. Soil organic matter was determined by loss on ignition and P determined colorimetrically (4). An analysis of variance was performed on the data to separate treatment differences.

In the soil containing 635 ppm Pb, the addition of 100 ppm or greater P significantly decreased the amount of Pb taken up by the plant; however, in the 3520 ppm Pb soil, 215 ppm P or greater was necessary to prevent the uptake of Pb (Fig. 1). These data support the work of Zimdahl and Foster (15), who found that P had to be increased to offset an increased level of Pb in the soil. However, even after reducing Pb uptake by 36–40%, these authors still showed high levels of Pb taken up by corn plants (34 $\mu g \cdot g^{-1}$ dry weight). Other researchers have shown that, while the amount of available P influences Pb uptake, it is significantly less useful than pH or cation exchange capacity as a factor

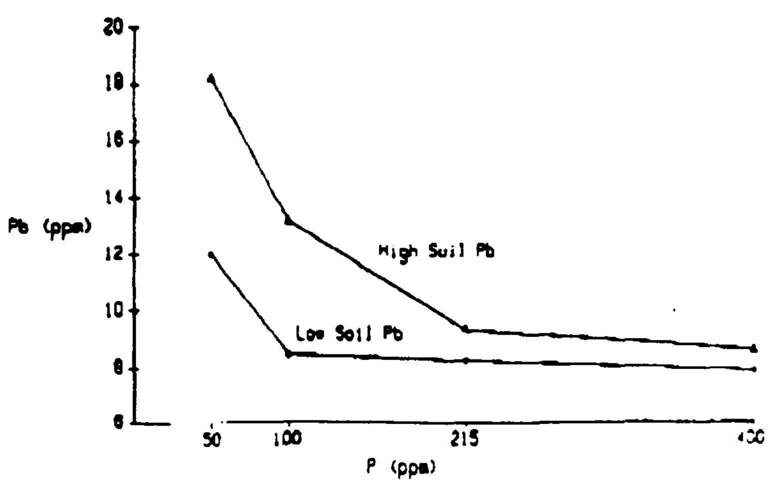

Fig. 1. The effect of 4 levels of P on Pb uptake by lettuce grown on soils containing high (3520 ppm) and low (635 ppm) Pb levels. N = 6, LSD (5%) = 3.183 ppm.

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[1]Assistant Professor

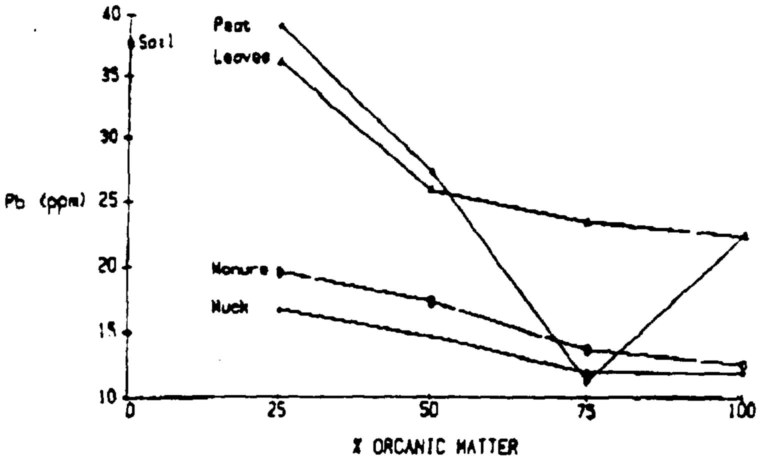

Fig. 2. The effect of 4 types of organic matter soil amendments in varying proportions on Pb uptake in lettuce grown in soil containing 3520 ppm lead. N = 3, LSD (5%) = 6.432 ppm.

limiting Pb uptake (5, 15). Nevertheless, in the soil with the highest Pb level (3520 ppm), the addition of 215 ppm P prevented Pb from being taken up in concentrations greater than that taken up from the uncontaminated soil control (9 $\mu g \cdot g^{-1}$ dry weight) (Fig. 1). From the practical level, however, this much P may have no additional benefits for plant growth other than preventing Pb uptake and may be harmful by reducing the availability of soil micronutrients.

The addition of organic matter, however, to Pb-contaminated soils seemed a more promising method of preventing Pb uptake in that there are many inexpensive sources available to city gardeners, while the addition of organic matter would have additional beneficial effects on plant growth and soil structure. Three readily available sources of organic matter (leaves, spaghnum peat, and well-decomposed manure) plus an organic muck soil collected near Ithaca, N.Y. were compared in effectiveness in preventing Pb uptake in a soil of 3520 ppm Pb content. The background levels of lead in these organic amendments were as follows: leaves, 32 ppm; peat, 11 ppm; manure, 29 ppm; and muck soil, 45 ppm. Lettuce uptake of Pb in contaminated soil without organic amendment was 37.6 $\mu g \cdot g^{-1}$ dry weight. Lettuce grown in the control noncontaminated soil had a Pb uptake of 9 $\mu g \cdot g^{-1}$ dry weight. The 2 best soil amendments were muck and manure, which showed a 73% and 63% reduction of Pb uptake, respectively, in soils with a 25% (by volume) addition of organic matter (Fig. 2). Peat and ground leaves were the least effective amendments, showing reductions in Pb uptake of only 55% in the 100% organic matter treatment. These latter 2 treatments, however, may have been confounded by their low pH (4.4 and 3.7, respectively) while the pH of manure and muck soil were 6.7 and 7.4, respectively. Numerous authors have cited the effect of low pH on increasing Pb uptake, and these results would tend to support their observations (1, 5, 15). However, the unamended soil pH was 6.8, refuting the idea that high pH alone is sufficient to prevent Pb uptake.

Although many researchers have reported the importance of increased cation exchange capacity and organic matter in reducing Pb uptake (9, 10, 15), few have added organic matter of different types and volumes so that the urban gardener could use the results practically. Liebhardt and Koske added up to 50% (by volume) of a commercially available composted refuse containing 300 ppm Pb to soil and found no significant Pb uptake in ryegrass and corn but did find increased uptake in snapbeans and soybeans (7). Zimdahl and Foster reported that the addition of 6% cow manure reduced Pb uptake in corn shoots and roots from 56 $\mu g \cdot g^{-1}$ dry weight to 25 $\mu g \cdot g^{-1}$ and 85 $\mu g \cdot g^{-1}$ to 48 $\mu g \cdot g^{-1}$ dry weight, respectively (15). This study, however, did not counteract the diluting effect of added organic matter by adding additional Pb.

Lettuce plants that were "gassed" with engine exhaust containing Pb showed elevated Pb levels (17.2 $\mu g \cdot g$ dry weight) compared to the ungassed controls (9.3 $\mu g \cdot g^{-1}$ dry weight) (Fig. 3). Washing with water alone removed only some of the Pb, while the addition of acetic acid or liquid detergent to the water removed it to a level equal to that of the ungassed controls. Preer et al. (13) washed leaves of lettuce that had been growing near a heavily traveled road in water and removed 70% of the Pb found in the leaf.

We conclude that lettuce grown in Pb-contaminated soil can be prevented from taking up Pb by the addition of P at or greater than ≥100 ppm P or by the addition of 25% (by volume) organic matter in a form such as composted manure or muck soil. Although additional P was effective, it may cause unavailability of soil micronutrients and may be a costly item for urban gardeners. From a practical level, organic matter amendment is preferred because of its effectiveness, inexpensive availability, and additional benefits for plant growth and soil structure.

Lead particulates are effectively removed from lettuce leaves by the addition of dilute acetic acid (vinegar) or liquid detergent to the wash water.

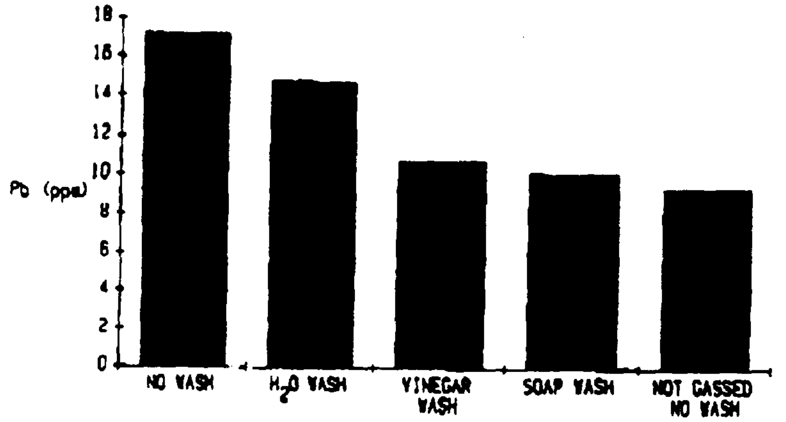

Fig. 3. The effect of washing treatments on Pb levels in lettuce leaves exposed to gasoline engine emissions. N = 5, LSD (5%) = 2.347 ppm.

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Transmission of *Xanthomonas campestris* pv. *pruni* in Plum and Apricot Nursery Trees by Budding

C.A. Goodman and M.J. Hattingh

Department of Plant Pathology, University of Stellenbosch, Stellenbosch 7600, South Africa

Additional index words. bacterial spot, budwood, *Prunus armeniaca*, *Prunus salicina*, rootstocks

Abstract. **A study was made of the importance of the source of apricot (*Prunus armeniaca* L.) and plum (*P. salicina* Lindl.) buds on subsequent development of bacterial spot caused by *Xanthomonas campestris* pv. *pruni* (Smith) Dye on scion shoots and their rootstocks. Visibly infected buds budded onto 'Marianna' rootstock took poorly, and all developing shoots became infected. Symptomless, suspect buds from diseased trees had an increased rate of take, and fewer shoots were infected. Visually healthy buds collected from healthy trees gave the highest rate of take and lowest percentage of shoot infection.**

Bacterial spot of stone fruit caused by *Xanthomonas campestris* pv. *pruni* (Smith) Dye sporadically causes heavy crop losses in certain fruit-growing areas of the Western Cape Province of South Africa. Apricot, peach [*Prunus persica* (L.) Batsch], and Japanese plum are the most severely affected economic hosts. Recent large plantings of nectarine [*P. persica* var. *nectarina* (Ait.) Maxim.], particularly the late-maturing cultivars, are also threatened.

Most stone fruit trees in South Africa are produced in November and December (equivalent to June budding in the Northern Hemisphere). If the bud does not take, the rootstock is sometimes cut back below the dead bud and rebudded. Furthermore, budwood of stone fruit trees might contain buds that are visually infected with *X. campestris* pv. *pruni*. Some nurserymen believe that these buds will always die and therefore do not transmit the pathogen. It is also not known what risk there is in using visually healthy budwood derived from diseased trees or from apparently healthy trees in an infected orchard. This investigation considers transmission of *X. campestris* pv. *pruni* from different budwood sources.

Rootsocks were established in the open ground. Before planting, the soil was treated with ethylene dibromide for nematode control, and various fertilizers and dolomitic lime were applied as recommended after soil analysis. Irrigation was by overhead sprinklers. Granular fertilizer and nutrient sprays were applied during the growing season. Routine pest and disease spray programs were followed, but antibiotic or copper sprays were avoided.

Budwood was cut at random from 4-year-old plum trees in an orchard where about 70% of the trees exhibited severe symptoms of bacterial spot. On affected trees, branch cankers and leaf lesions were well-developed. Budwood also was taken from 6-year-old apricot trees in an orchard where about 15% of the trees had symptoms of the disease. A distinction was made between visually healthy buds obtained from apparently healthy trees, suspect buds that appeared to be healthy but were obtained from diseased trees, and infected buds from branches with cankers extending into the base of the bud.

Budwood and rootstock material, time of budding, and number of buds inserted per combination are listed in Table 1. The inverted T-bud method (8) was used. Rootstocks were planted at 15-cm intervals in rows 1 m apart. 'Marianna' (*P. cerasifera* Ehrh. × *P. munsoniana* Wight & Hedr.) rootstock cuttings were planted in spring, and apricot rootstock were grown from seed planted the previous spring. Shadecloth (3 m high) was used to separate rows grafted with infected buds from those grafted with suspect and visually healthy buds. Results were recorded 8 weeks after budding, but secondary spread of the disease was monitored for 6 more weeks.

Isolation and identification of X. campestris *pv.* pruni *from infected shoots.* Plum and apricot shoots were surface-disinfested with 70% ethanol and flamed. Diseased shoot tissue was excised aseptically, placed in a 20-ml, screw-cap bottle containing 10 ml sterile buffered saline (12), shaken vigorously for several minutes, left for 2 hr, reshaken, and loopfuls of the suspension streaked onto Difco nutrient agar. Pure cultures of *X. campestris* pv. *pruni* were obtained by repeated subculturing on nutrient agar. The identity of the pathogen was confirmed by the spot test (1) using the specific bacteriophages FII and FIV (7).

Development of bacterial colonies on nutrient agar indicated that infected, suspect, and visually healthy plum and apricot buds generally contained numerous, few, and no *X. campestris* pv. *pruni* cells, respectively, at budding. Successful take of visually infected plum buds was low (<50%), and all shoots developing on 'Marianna' rootstock from these buds were diseased 8 weeks after budding (Table 1). The pathogen was readily isolated from diseased shoot and leaf tissue of both plum and apricot. Infected shoots were severely stunted and usually had a canker at the graft union and at one or more sites on the shoot. Often, cankers almost girdled the shoots, causing some to snap off in strong wind. Leaf infection was severe, and spots usually coalesced to form ragged holes. Many leaves were deformed, and heavily infected ones had a silvery sheen. Infected shoots were thinner than those developing from visually healthy buds. Of the 'Marianna' rootstocks on which infected buds did not take, 65% produced watersprouts. Most (88%) of these watersprouts developed cankers and leaf spots typical of bacterial spot.

Bud take of suspect plum and apricot buds on 'Marianna' was reasonably high (62–90%). Shoot infection was reduced (43–67%), but symptoms were similar to those resulting from

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Jile Lead

COMMUN. IN SOIL SCIENCE AND PLANT ANALYSIS, 10(9), 1195-1210 (1979)

A STUDY OF SOIL CONTAMINATION AND PLANT LEAD UPTAKE IN BOSTON URBAN GARDENS

KEY WORDS: Lead, vegetable gardens, toxicity

Thomas M. Spittler and William A. Feder[15]
U. S. Environmental Protection Agency
Surveillance & Analysis Division - Region 1
60 Westview Street
Lexington, MA 02173

ABSTRACT:

This study has demonstrated a serious problem of Pb contamination in the normal environment of many urban residents. Many soil samples have been analyzed by X-ray fluorescence spectroscopy from backyard and play areas as well as from large community gardens and playgrounds. An average Pb level of 800 ppm was found in about 900 soil samples. The elevated Pb levels are definitely traceable to widespread use of Pb paint in the past. Tissues of selected plant species grown in garden soils containing Pb levels ranging from 100-2000 ppm showed differing affinities for Pb uptake. The amount of Pb found in tissues was generally related to the soil Pb concentration but was also organ or tissue related; fruits taking up less than roots and roots less than tops. Experimental design insured that the soil was probably the sole source of Pb in this study. This points to positive translocation of Pb from soil into plant tissue.

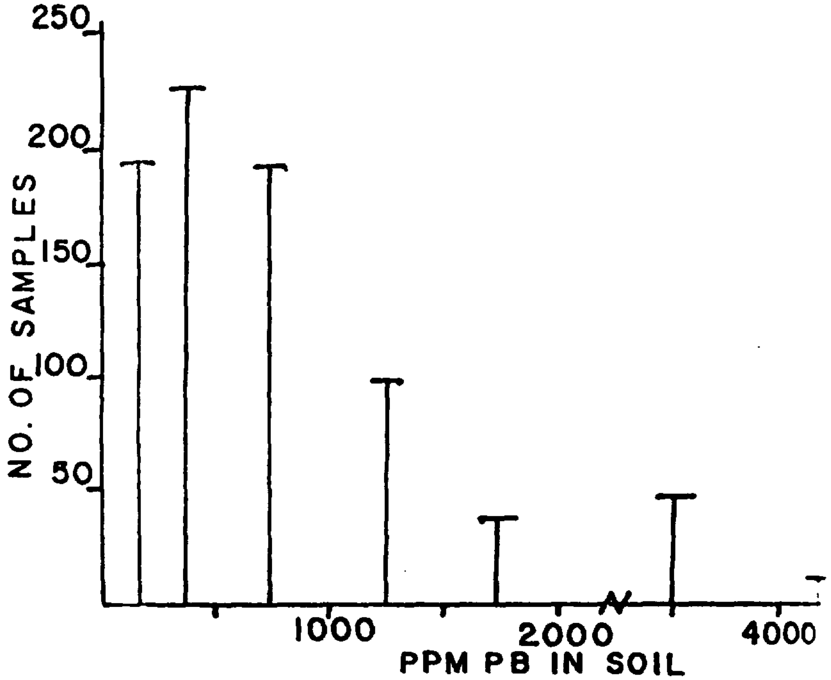

Figure 2. Histogram of Pb Variation in 900 Garden and Pla. Soil Samples.

these elements could be paired with varying high soil Pb concentration. These data, and the inference from Figure 1, pointed to leaded paint as a significant source of soil contamination in yards, gardens, and vacant lots--since turned into playgrounds and community gardens.

During this same summer and fall, several vegetation samples were collected from urban gardens and analyzed at private laboratories. Levels as high as 30-50 ppm Pb (D.W.) indicated that plant uptake could be a serious problem (Figure 4). Typical market basket vegetation has been found to contai 1-5 ppm Pb (D.W.)[8].

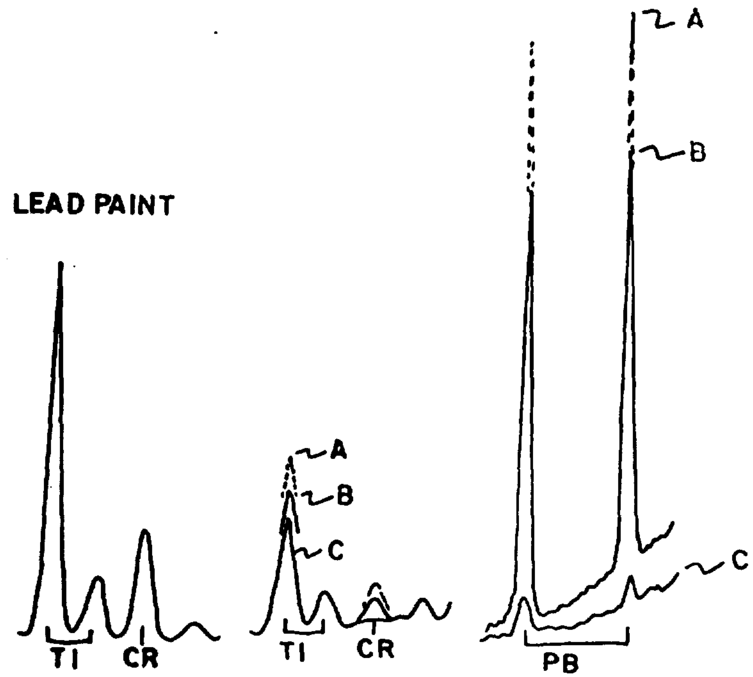

Figure 3. Evidence for Pb Paint Contamination of Garden Soil.

Three important questions emerged from these preliminary analyses: (1) Was there any relationship between soil lead content and edible plant uptake? (2) What was the variation of lead uptake with plant species? (3) Was it possible to differentiate soil lead translocation from airborne lead contamination of vegetation? This study addressed itself to these questions.

MATERIALS AND METHODS

Seven gardens were selected from those tested. Pb levels ranged from 100-2000 ppm. Approximately 55 gallons of soil

TABLE 2

Moisture Content of Vegetation Samples

Crop Type	Plot Number 1	2	3	4	5	6*	7	8
	- - - - % Moisture - - - -							
Bean								
Fruit	84	88	88	94	87	-	88	90
Radish								
Top	91	-**	-	90	93	88	91	91
Root	96	-	-	95	96	93	93	93
Beet								
Top	90	88	93	88	90	-	89	90
Root	76	77	81	86	79	-	76	89
Carrot								
Top	74	78	77	-	83	-	77	78
Root	82	86	85	-	86	-	83	82
Lettuce								
Top	97	93	94	93	97	-	93	93

*Only one crop harvested. As-sterile soil.

**Recovery data not recorded.

analysis of soil from any one plot showed good uniformity of mixing. Except for two plots (#2 and 8), six aliquots showed variations of lead content of less than ± 17%. Even this inhomogeneity is minimized by combining all plant tissue from any one crop into a single sample prior to analysis.

Calibration of the XRF instrument was first performed using portions of Pb-free fine-grained sand which were spiked with $PbCl_2$. These samples served as rough comparison standards

but, in a subsequent interlab study, were found to give high results for soil Pb analysis. A second set of standards was prepared from four of the garden soils as follows: About 10-g sieved soil was thoroughly mixed for homogeneity. Two gram aliquots of these samples were spiked with standard AA Pb solution to yield spikes containing approximately 1/2 x, 1 x, 1.5 x, and 2 x Pb where x is the estimated Pb content of the soil sample. Standard addition plots (Figure 5) were then made by analyzing each set of spikes plus one unspiked aliquot of each soil. The set of four unspiked samples then became a reference set of soils for future comparison with Pb contaminated soil. These data agreed well with analyses performed by four outside laboratories on split samples. (Article in preparation.)

Plant tissue analysis was also done by the XRF technique. Pb has a sensitivity limit of 5-10 ppm in a low atomic weight matrix. To increase sensitivity, 2.0 g dry tissue were placed in a porcelain crucible and muffled to 550°C for about 2 hours. Temperature was raised about 100°C/30 min. starting at 200°C. This procedure gave slow and almost complete ashing of organics and reduced sample weight by a factor of 4-20. This technique was tested by spiking vegetation samples with Pb solution before and after ashing. Pb losses were estimated at less than 15% due to the muffling procedure.

This technique was further checked against three outside labs by splitting eight vegetation samples with the USDA lab in Beltsville, MD. under Dr. Rufus Chaney, an MIT lab under Dr. James Fox and the University of Lowell Chemistry lab under Dr. Robert Litman. Comparative data and methodology are shown in Table 3. Finally, the NBS Reference Sample Orchard Leaves #1571 was analyzed by the XRF method in our laboratory. Recovery of the Pb was about 85%.

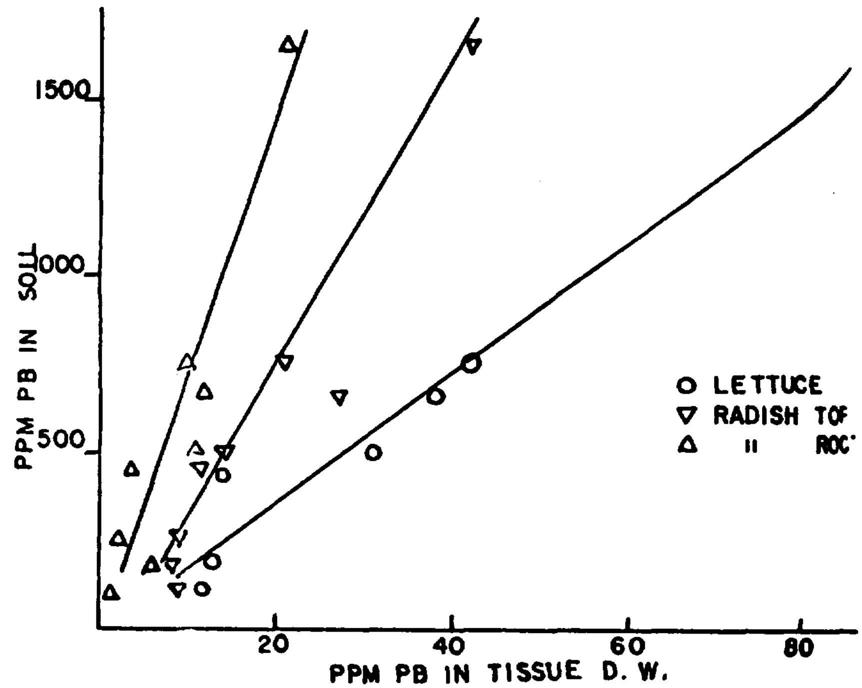

Figure 6. Pb Content of Lettuce and Radish Grown in Urban Garc Soils Under Greenhouse Conditions.

tion permit us to conclude that we are measuring soil Pb uptake almost exclusively. Were these same vegetables grown under normal gardening conditions, one could expect some added contamination from aerial deposition of aerosol Pb, wind-stirred soil Pb, and accidental contamination from soil Pb owing to cultivation practices.

Based on the results of this study, recommendations to the Boston Gardening Community for the 1978 season for gardens with high lead levels (> 1,000 ppm), were to confine gardening in such soils to fruiting crops which showed minimal Pb uptake

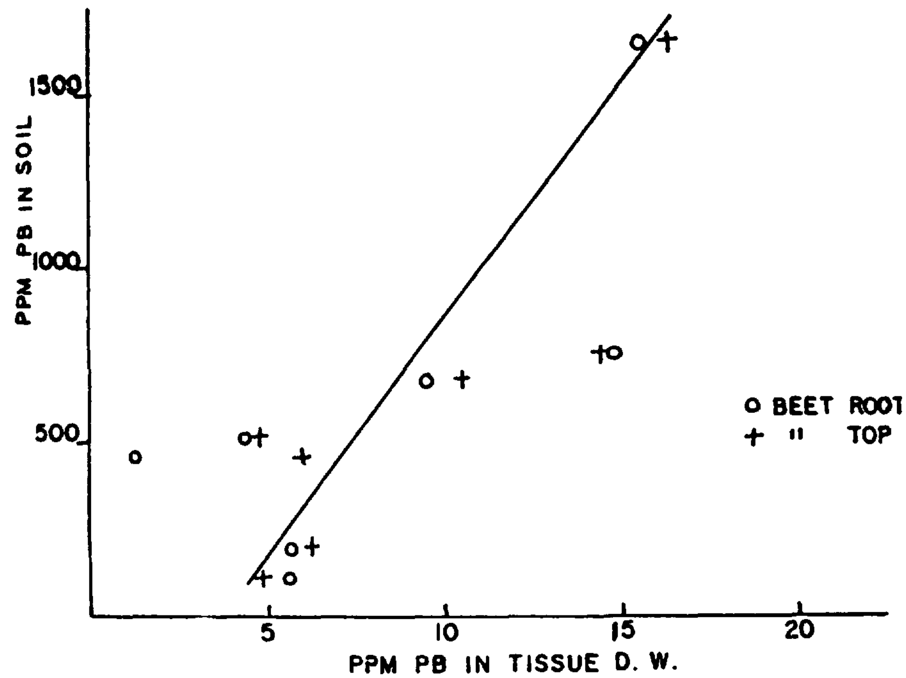

Figure 7. Pb Content of Beet Tops and Roots Grown in Urban Garden Soils Under Greenhouse Conditions.

even in highly-contaminated soil. Where soil Pb was in the medium range (500-1000 ppm), gardeners were advised to avoid leafy greens or develop container plots of clean soil for such crops. Harvesting plant tops (e.g., beets, turnips) was also discouraged in these gardens.

Aside from the obvious conclusions of increased dietary Pb that could result from consuming contaminated vegetables, the general problem of contaminated soil should also be noted here. Young children have an inherent closeness to the soil and are often observed to put soiled fingers and food into their

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TRIBUTION OF DTPA-EXTRACTABLE FE, ZN, AND CU IN SOIL PARTICLE-SIZE FRACTIONS[1]

ITIONAL INDEX WORDS: Soil particle-size fractions, micronutrients.

Adam Khan[2]
Department of Agronomy
University of Illinois

TRACT:

To examine the distribution of DTPA-extractable Fe, Zn, and in clay, silt, and sand fractions; surface soils were collected om cultivated fields of North Dakota, South Dakota, West Virginia, wa, Ohio, and Illinois. Clay, silt, and sand fractions were parated after sonic dispersion of soil water suspension and anazed for DTPA-extractable Fe, Zn, and Cu. In general, clay had the ghest and sand the lowest amount of DTPA-extractable metals. nsequently, clay had the highest and sand the lowest intensity and pacity factors for these metals since DTPA micronutrient test easures both these factors.

INTRODUCTION:

The distribution of DTPA-extractable Fe, Zn, and Cu in clay, silt, and sand fractions partly depends upon the amount and nature of surfaces and solid phases which control the solubility of these metals. DTPA forms soluble complexes during extraction and there-